Assessing Plankton and Particles with an Autonomous Imaging LOPC

David M. Checkley, Jr.
Integrative Oceanography Division 0218
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0218
phone: (858) 534-4228 fax: (858) 822-0562 email: dcheckley@ucsd.edu

Alex W. Herman
Integrative Oceanography Division 0218
Scripps Institution of Oceanography
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0218
phone: (902) 426-2447 fax: (902) 426-2256 email: hermana@mar.dfo-mpo.gc.ca

Award Number: N000140610181
http://checkley.ucsd.edu

LONG TERM GOALS

We wish to characterize and quantify particles and plankton in the pelagic ocean, to enable an understanding of their dynamics and their roles in ecosystems and biogeochemical cycles. Characterization and quantification are also necessary to describe the distribution and abundance of particles and plankton in the sea in relation to the environment, including its acoustic and optical properties.

OBJECTIVES

Our objective is to integrate the Laser Optical Plankton Counter (LOPC, Herman et al. 2004) with a video imaging system, REFLICS (REal-time Flow Imaging and Classification System, Iwamoto et al. 2001), and deploy this on a motored autonomous underwater vehicle (AUV). The result will be an instrument capable of autonomously assessing the distribution, abundance, size, and type of plankton and particles of 100 μm – 2.5 cm equivalent spherical diameter (esd). The novelty and strength of our work derives from combining video imaging, with its high resolution, the LOPC, with its high sampling rate, and the AUV, with its autonomous and quiet performance, to provide data useful for predictive models. Computer analysis of video images allows the classification of the plankters and particles that comprise dominant features of the size spectrum measured by the LOPC. Our intent is that this system will be commercialized for general use in measuring properties necessary to understand and predict optics and acoustics of coastal seas.

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APPROACH

We proposed three tasks: 1) transition of REFLICS from the lab to operate *in situ*; 2) integration of REFLICS and the LOPC for use on an AUV; and 3) development and proof-of-concept deployments. REFLICS was originally designed for use in a laboratory. We have preserved the simple yet effective operating principles of REFLICS while miniaturizing some components, reducing overall power consumption, and designing and fabricating an underwater housing. The LOPC has also been modified for use in the AUV, e.g., in regard to power consumption and weight. The Bluefin AUV payload and nosecone sections have been modified to accept REFLICS, the LOPC, and a CTD. Deployments will be on the Dorado AUV of the Monterey Bay Aquarium Research Institute (MBARI).

WORK COMPLETED

The following tasks have been completed: 1) machining and fabrication of mechanical components, 2) acquisition of redesigned LOPC, 3) acquisition of AUV payload section and fabrication of the frame for mounting LOPC & REFLICS, 4) assembly and testing of the underwater REFLICS, 5) LOPC power board development and testing and reprogramming of the LOPC firmware, 6) assembly of internal components of the AUV payload section, and 7) acquisition of images of zooplankton at sea and in a flume on the SIO pier.

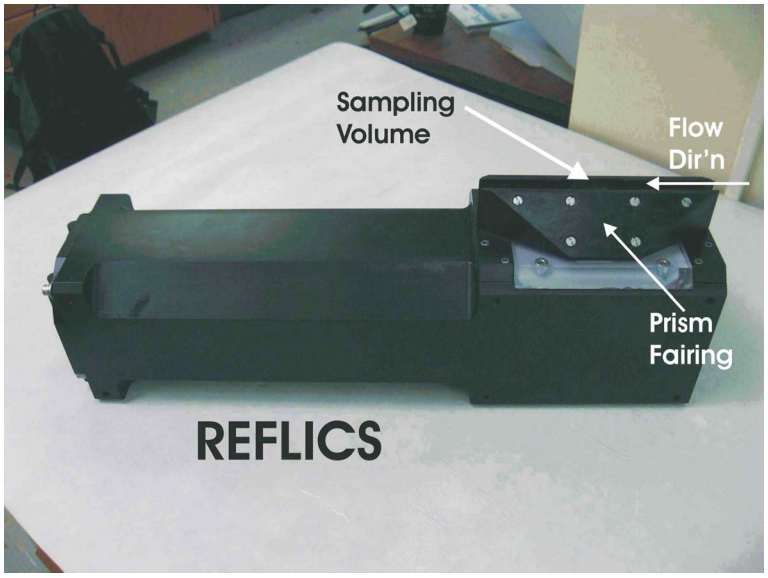

Figure 1. REFLICS in its pressure case. [REFLICS is black, lying flat, and is 11-cm in diameter and 71-cm long. On the right is the sampling volume, which is bounded on the bottom by an optical window and on the sides by the two prisms, which reflect light from the optical window through the sampling volume and back into through the optical window. The direction of flow is from right to left.]

The uniqueness of the optical design lies in the use of two, right-angled prisms which apply 2 x 90^0 reflections to the emerging light beam thus return it back to the case via an acrylic window (Fig. 1). As a result of this optical design, only a single pressure case is required. The sampling volume is surrounded by the two prisms, which face one another and are separated by a distance of 1.2 cm. The

prisms are housed inside aluminum fairings (not shown), which provide optimal, undisturbed flow and also mechanical protection. The 'effective' volume sampled by each 512 x 512 frame is 3.8 milliliters.

In addition to tests in the lab and off San Diego in 2007 (reported last year), REFLICS was tested in the pier flume at SIO in spring 2008, using lab-reared plankton.

RESULTS

REFLICS Camera System

As previously reported, the REFLICS was tested on the RV Sproul in April 2007. The case was mounted within a protective frame and 'yo-yoed' by winch from 3-8m depth at speeds of 1 m sec^{-1}. The tests were useful in pointing out required software improvements and modifications. Although auto-startup and data logging were successful, lab tests indicated that there was potential for auto-start failure at sea in the event of brief loss of power from the power source in the AUV. Further software protection was added by software engineers at Brooke-Ocean. In addition, the WINDOWS file/directory architecture resulted in extremely slow data downloading of small but numerous *.tiff image files produced by the camera system; approximately 10-12 hours were required to download 300,000 images (total ~1 MB). A multi-layered directory/subdirectory system was added to the data logging path, resulting in a significant reduction (~90%) of download times.

During June 2007, the components boards of the camera system suffered physical damage during customs inspection while being shipped from SIO to BIO. The PC-104 computer board, power boards, HD drives and cables/harnesses were replaced at BIO. The PC-104 software was installed and the system was re-tested and shipped to SIO. REFLICS then underwent a series of tests in an outdoor seawater flume tank situated on the Scripps pier. Configured as a trough of a square cross-section ~30 x 30 cm, the flume tank provided flow speeds of ~ 0.7 m sec^{-1}. In the first series of tests, bubbles were introduced in the flow path and in the second series of tests, white sea bass eggs and larvae and *Artemia*, provided by the Hubbs Research Institute, were introduced. Images of these zooplankton, acquired in April 2008 in the SIO pier flume, are shown in Fig. 2.

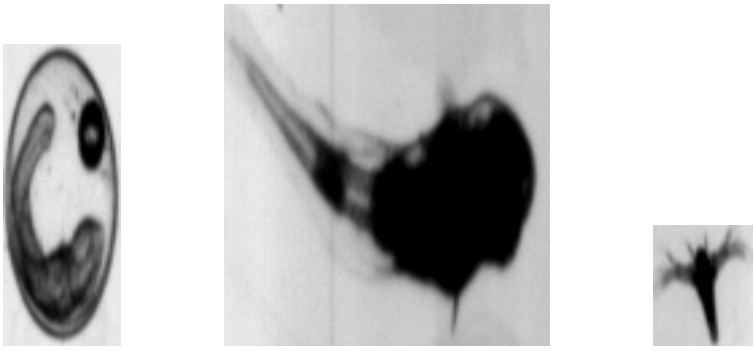

Fig. 2. Images of zooplankton obtained during use of REFLICS in SIO pier flume. Each image has been segemented, in real time, from a 512 x 512 pixel image and written to file. [The three grayscale images are, from left to right, an oblong fish egg (~ 1.4mm long), a fish larva (~3mm long), and an* Artemia *(~ 0.8 mm long).]

Laser Optical Plankton Counter

The final operational software was installed in the LOPC in late 2007. The LOPC was tested in the Bedford Basin near BIO in December 2007. Several operational principles were instilled in the software design:

i) data should only be stored during the AUV dive cycle, and not while the AUV is at surface telemetering its position,
ii) data acquisition should be started & stopped at depths well below the surface, removed from wave-action that might re-trigger acquisition, and
iii) data from the triggered depth to surface should not be lost accidentally.

During operation, the LOPC is constantly storing data in a memory buffer representing a past-period ranging from 'current time' to a past time (up to 120 seconds, user-selectable). The software was designed to start acquisition at a user-selected depth and, once triggered, the 'past data', typically representing current depth-to-surface depth, are immediately stored. Once acquisition is triggered at the prescribed start depth, a user-selected 'dead period' is initiated during which re-triggering is blocked. The 'stop-acquisition' sequence is initiated when the AUV ascends to a depth equal to the start depth plus 1 m. Once this sequence is initiated, data are acquired and stored for another user-selectable period (up to 120 seconds). Acquisition is terminated while the AUV breaks the surface. Operationally, the LOPC acquisition can be triggered at depths well below wave action while ensuring inclusion of near-surface data.

The LOPC was tested in the Bedford Basin near BIO on a stationary, anchored naval barge used for acoustics calibrations. Start-acquisition depths of 5-15 m were tested and the LOPC was lowered to 35 m and recovered. Various configurations of near-surface 'yo-yoing' were also performed to test acquisition software stability. Testing indicated the software acquisition was performing well and cycling data were logged successfully to onboard flash storage media. The LOPC was shipped to SIO in February 2008.

AUV Payload Section

Prior to this reporting period, the AUV payload section, used to house REFLICS, LOPC, and a CTD, was designed, fabricated, assembled, and shipped to MBARI for inspection and measurement by their engineers. During September-October, 2008, the payload section was at MBARI, with associated electronic instruments, being fitted with syntactic foam required for buoyancy adjustment.

Sea Trials

The first sea trials of the REFLICS-LOPC system were scheduled for April 2008 following return of the R/V ZEPHYR from the Gulf of California to MBARI. Ship problems resulted in delays of the MBARI program and, as a result, our sea trials were postponed. The first sea trials of the system are scheduled for November 5, 2008. A second cruise is scheduled for spring 2009.

IMPACT/APPLICATIONS

Our objective is to create an autonomous instrument capable of assessing particles and plankton in situ. Further, we are attempting to create the underwater version of REFLICS, for use independently or with

the LOPC on an AUV, for general use, commercial production, and with a reasonable cost. We anticipate that our system (AUV, LOPC, and REFLICS) and REFLICS alone will be of significant value to marine scientists assessing and investigating particles and plankton in situ.

TRANSITIONS

No transitions have occurred.

RELATED PROJECTS

Checkley and Herman, with Russ Davis (SIO) and George Jackson (TAMU), have a Major Research Instrumentation grant from NSF is to create the SOLOPC, a profiling, Lagrangian, autonomous float consisting of a SOLO float, LOPC, fluorometer, and Iridium communication (Checkley *et al.* 2008). Modifications to the LOPC made for the NSF MRI project have been transferred to the present project with REFLICS and the AUV. In addition, important characteristics of the float (SOLOPC) and envisioned AUV are similar in important ways, particularly being autonomous and free from ship motion, thus giving us confidence that the present project with REFLICS, LOPC, and the AUV will succeed. The general principle of sampling plankton and other particles from autonomous platforms is being well established through the development and use of both the SOLOPC (NSF) and REFLICS (ONR).

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PUBLICATIONS

None.

PATENTS

None.

HONORS/AWARDS/PRIZES

None.